

**UNIVERSITI TEKNOLOGI MARA**

**MICROSTRUCTURAL AND  
MECHANICAL PROPERTIES OF  
WELDED Ti-15-3 BETA TITANIUM  
ALLOY USING GTAW WITH  
BORON-MODIFIED FILLERS**

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Thesis submitted in fulfillment  
of the requirements for the degree of  
**Doctor of Philosophy**

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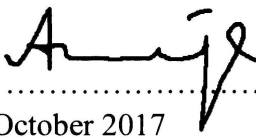
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## ABSTRACT

Mechanical properties of titanium alloys are dictated by their microstructure, particularly the size, shape and distribution of hexagonally close-packed (hcp)  $\alpha$  and body-centred cubic (bcc)  $\beta$  phases. For metastable  $\beta$  titanium alloys the morphology and distribution of  $\alpha$  precipitates have largely contributed to its mechanical properties. Welded zones in gas tungsten arc welding (GTAW) of metastable  $\beta$  titanium alloys exhibit retained  $\beta$  structure with inferior mechanical properties due to coarse columnar prior  $\beta$  grains and lack of  $\alpha$  precipitates in the matrix in as-welded condition. In this work refinement of prior  $\beta$  grains and  $\alpha$  was achieved in GTAW welds of metastable  $\beta$  titanium alloy, Ti-15V-3Cr-3Al-3Sn (Ti-15-3) by current pulsing and modification of welding fillers. Autogenous pulsed current GTAW were performed at 0, 2, 4 and 6 Hz pulsing frequencies to determine optimum frequency for pulsed current welding of thin plates Ti-15-3 alloy. Welding of Ti-15-3 alloy using commercially pure  $\alpha$  titanium (CP-Ti) alloy filler resulted in the precipitation of  $\alpha$  phase from  $\beta$  phase during cooling to ambient temperature due to dilution of melted base metal with the filler metal. The GTAW welds with CP-Ti filler exhibit high hardness, higher tensile strength but lower % strain as compared to the autogenous weld owing to precipitation of  $\alpha$  phase precipitation at  $\beta$  grain boundaries. Addition of 0.5 wt.% and 1.0 wt.% boron to CP-Ti fillers resulted in significantly refined fusion zone  $\beta$  grains in welds with CP-Ti-0.5B and CP-Ti-1.0B fillers due to growth restriction mechanism associated with partitioning of boron during solidification. X-ray diffraction (XRD) analysis of autogenous welds showed only bcc  $\beta$ -Ti phase while indexed peaks for the weld samples with CP-Ti filler showed the presence of very small hcp  $\alpha$ -Ti phase along with bcc  $\beta$ -Ti phase. Welds with CP-Ti-0.5B and CP-Ti-1.0B fillers showed additional orthorhombic TiB peaks. Mechanical tests show that hardness of the fusion zone and tensile strength in welds with boron-added CP-Ti fillers are higher than that in autogenous welds and welds with CP-Ti filler. Post-weld heat treatment (PWHT) of the welded samples increased  $\alpha$  precipitation in all samples while FESEM and TEM analysis of the fusion zones showed  $\alpha$  with higher aspect ratios in aged welds with boron-added CP-Ti fillers than autogenous weld and weld with CP-Ti filler, attributed to the additional nucleation sites provided by increase in boundary area of refined prior  $\beta$  grains with the addition of boron. PWHT weldments displayed higher hardness values, compared to similar regions in as-welded samples, and higher tensile strength after aging.

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